HYDROLOGIC CYCLE:

1. Cartoon picture (AH: fig 1.4)
2. Schematic with outline of part we are interested in. (AH: fig. 1.5)

IMPORTANCE OF GROUNDWATER (why do we care?)

1. Earth's water budget (AH: sec. 1.3):

Oceans	97.2%
Land-based	2.8%
Atmosphere	0.001%

2. Land-based water budget:

	% of total	% of land-based
Ice-caps and glaciers	2.14%	72.7%
Groundwater (to 4000 m)	0.61%	22.0%
Soil moisture	0.005%	0.18%
Fresh water lakes	0.009%	0.32%
Saline lakes	0.008%	0.29%
Rivers	0.0001%	0.004%

3. Fresh water use in US (two graphs, AH: figs. 1.1 and 1.2)

4. Potable water treatment requirements:

Groundwater: disinfection/softening
Surface water: disinfection
flocculation/sedimentation (remover particles, color)
filtration (remove more stuff)

5. Regulations: CERCLA, RCRA, UST, etc.

GEOLOGIC TERMS (Bear, Fig 1.1.3):

Aquifer: Geologic stratum that contains and yields "significant" amounts of water.

Aquaclude: Geo. stratum that contains water but cannot transmit it in "significant" amounts.

Aquatard: Geo. stratum that contains water but can only transmit the water slowly.

Types of Aquifers:

Confined/Unconfined: - unconfined = potentiometric surface = water table
Leaky: aquifer confined by aquitard
Artesian: potentiometric surface > ground surface
Perched: discontinuous, above vadose zone.
Consolidated/Unconsolidated: sandstone vs. sand
Fractured/Fissured: solution cavities (karst) or fractures (basalt, granite)

Potentiometric or piezometric Surface: elevation that water will rise in a well

Vadose Zone: Portion of aquifer where pores spaces are occupied with water and air (unsaturated zone).

Capillary Fringe: saturated zone above water table due to capillary rise.

Soil: - unconsolidated material.
Agricultural def: "Top soil" or tillable material (limited to a few inches from surface).
Soil Science def: Mineral, organic, water and gas phases (soil ≠ solid matrix), including living organisms, to include all unconsolidated material from surface to bedrock.

Aquifer Material: Solid matrix of aquifer (mineral and organic). May be consolidated or unconsolidated, usually has low organic content. Used to differentiate from agricultural definition of soil.

POROUS MEDIA DEFINITIONS:

Porous Medium A heterogeneous system of voids and solids.
solid: persistent presence (hint: REV) (Bear)
can be organic or inorganic (Rao)
can have reactive interfacial boundaries (Rao)
relatively high specific surface area (Bear)
pore spaces: at least some must be interconnected (not isolated) (Bear)
random distribution (various sizes/shapes) (Rao)
relatively narrow size openings (hint: capillary pres.) (Bear)

Representative Elementary Volume (REV): Concept that allows us to treat a discontinuous, multiphase system (i.e. a porous medium) as a CONTINUUM (allows use of differential equations).
indifference: REV is indifferent to the property of interest (n, K, etc.)
Select an REV that is sufficient for all properties.
invariance: REV req'd for the property is the same in space and time
insensitive: Any method used to measure the property requires the same REV
[graphic Dominico and Schwartz, fig 3-16, 3-17].

Porosity: n, ε = volume voids/volume of media (AH: table 4.3; Dominico & Schwartz, tables 2.1, 2.2)

Effective Porosity: n, ε = volume of interconnected voids/volume of media

Bulk density (of solid phase): ρ_b = mass of solids/volume of media (unit: $M\ L^{-3}$)

$$\rho_b = \rho_s (1 - n)$$

Saturation: S = volume of water/volume of voids
S = 1 = media is completely saturated with water

Water Content: θ = volume of water/volume of media
$\theta = n\ S$
$\theta = n$ = media is completely saturated with water

Hydraulic Head: h = Total energy/weight of water (unit: L)

$$h = z + \frac{p}{\rho g}$$

Fluid Flux or Darcy velocity: q = Volumetric flow rate/Cross-sectional area of media
$q = Q/A = v\ n$

SCOPE AND ASSUMPTIONS FOR THIS CLASS:

1. Incompressible Fluids {usually}

2. Nondeformable solid matrix (no shrinking or swelling) {usually}.

3. Fluid phases: water, air, NAPL
   Cover water flow and solute transport
   Won't cover air and NAPL flow (storage only)

4. Scales: Microscopic (pore) scale
   Macroscopic (Darcy) scale $\Rightarrow$ this class
   Megascopic (field) scale

TERMINOLOGY AND DEFINITIONS (from Rao, 1992)

Porous Medium: A heterogenous system, with presistent solid matrix (mineral and organic constituents) and containing a randomly-distributed, multiply-interconnected pores or voids of a broad range of sizes, shapes, lengths, and arrangements.

Fluid Phase: The fluid phase(s) contained in, and flowing through, the voids may be liquids or gases. Each fluid phase is considered to be homogeneous. The liquid phase may be an aqueous solution or water-immiscible liquid (usually referred to as a nonaqueous phase liquid [NAPL] or organic immiscible liquid [OIL]), and may contain dissolved (organic or inorganic) components. The fluid phases may be distributed such that each phase may be discontinuous.

Components (Solutes): The components of interest may be organic or inorganic. They may or may not interact with each other and/or the solid matrix. Thus, the components may be distributed in both the solid and fluid phases. These components may be subject to various biotic/abiotic transformations, which produce by-products, which are also of interest.

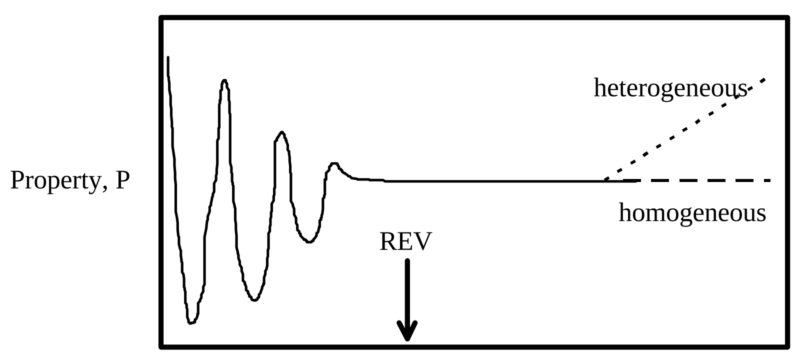
Continuum Concept:
- the real, discontinuous porous medium is replaced by a hypothetical, fictitious, but representative continuum.
- the macroscopic properties of the continuum are measureable and are differentiable over some specified domain (area or volume).

$$\lim_{x \to x_0} (P) = f(x_0)$$

- the macroscopic properties are defined over a Representative Elemetary Volume (REV) or a Representative Elementary Area (REA).
- REV (or REA) choice is based on the following criteria:
    - Indifferent to property (i.e., the chosen REV must meet the minimum size for all properties of interest).
    - Insensitive to method (i.e., REV choice must be independant of experimental technique used to measure the properties).
    - Invariant to space and time (i.e., REV must be the same at all locations within the domain as well as in time; however, this does not imply that the domain is homogeneous).

The various spatial scales of interest and the corresponding flow equations used are listed below:

- Microscopic (pore) scale: Navier-Stokes-Poiseulle equations.
- Macroscopic (Darcy) scale: Buckingham-Darcy-Richards equations.
- Megascopic (field or aquifer) scale: Stochastic subsurface hydrology concepts.



POROSITY: (See AH: chapter 4.2; Dominico and Schwartz: chapter 2.1)

Total Porosity = void space
= part of medium not occupied by solids

Two types: Original or primary porosity: created during "rock" formation
Secondary porosity: fissures, joints, fractures, solution cavities, karst

Rock Texture and Porosity: (AH: Fig 4.2; Dominico & Schwartz: Figure 2.1)

Well Sorted	High Porosity
Poorly Sorted (Well graded)	Low Porosity
Soluble Limestone	High Porosity

Porosity, n = V(voids)/V(total)

Ranges of Porosity: (AH: Table 4.3; Dominico & Schwartz: Table 2.1)

Sand	0.25 - 0.5
Clay	0.4 - 0.7
Karst Limestone	0.05 - 0.5

Effective Porosity: $n_{eff} \leq n$ because all pores may not be hydraulically connected

caused by:
1. Dead end pores
2. Unconnected pores

Total and Effective Porosity are related to grain size